Results of Monitoring of the Taman Peninsula Coastal Zone

Igor Podymov[1] and Tatiana Podymova[1,2]

[1] ***P.P.Shirshov Institute of Oceanology, Southern Branch, 353467 Gelendzhik, Russia***
Tel: + 7-86141-28281 Fax: +7-86141-28089
E-mail: podymov@coastdyn.ru
[2] ***E-mail: tpodymova@inbox.ru***

Abstract

Motions of higher order tectonic plates took place in 2011 at the Taman peninsula area. More than six hectares of new land that were bottom of the Sea of Azov had emerged in one night.

After two-year field studies and monitoring observations we estimated the scale of occurred events.

The following parameters were calculated using the acquired materials: average vertical velocity of plate motion; time of reaction of major tectonic plates under the influence of large-scale events; time of plate subduction before the restoration of equilibrium; a rate of coastline recession under the influence of natural factors during the process of equilibrium restoration; possibility of secondary movement of the higher order tectonic plates during the process of equilibrium restoration.

A hypothetical causal effect model of the occurred events was proposed as a result of these experimental studies. In accordance with the proposed model, the mechanism of the higher order tectonic plates interaction in the investigated region looks like “raised cock”, “twist-type trigger” for which will be possible the events, analogous to Tohoku earthquake (known as Fukushima earthquake). However, the tectonic processes taking place in the Earth interior demand keen attention. Economical activity in the region has to take them into account.

Introduction

The region of the Taman peninsula is very active in respect of tectonic processes. Mountains of Crimea and Caucasus are closing in this place. The environmental forecast of an extreme situation is bread-and-butter issue for the region. This task is not from a simple. People have encroached in potentially hazardous area in the course of the economic activities.

To secure all live against the natural phenomena happening in look-alike area, it is necessary to value correctly a degree of their hazard, and also to be trained in the forecast of extreme situations. At times, the inattention to processes will be worth much more expensively, than care to them in a daily life.

Detailed results of monitoring of the Taman peninsula coastal zone at the time of anomalous natural phenomenon are presented in the article.

Chronology of some events

The magnitude 9.0 Tohoku earthquake on March 11, 2011, which occurred near the northeast coast of Honshu, Japan, resulted from thrust faulting on or near the subduction zone plate boundary between the Pacific and North America plates. At the latitude of this earthquake, the Pacific plate moves approximately westwards with respect to the North America plate at a rate of 83 mm/yr, and begins its westward descent beneath Japan at the Japan Trench. Note that some authors divide this region into several microplates that together define the relative motions between the larger Pacific, North America and Eurasia plates; these include the Okhotsk and Amur microplates that are respectively part of North America and Eurasia. Eurasia plate has been moved to the east about 20 meters, as a result of earthquake (Karpova, 2011).

On April 30, 2011, more than six hectares of new land that were bottom of the Azov Sea had emerged in one night (Kryuchkov, 2011). The event has happened at the Kamennyi cape region (Fig. 1).

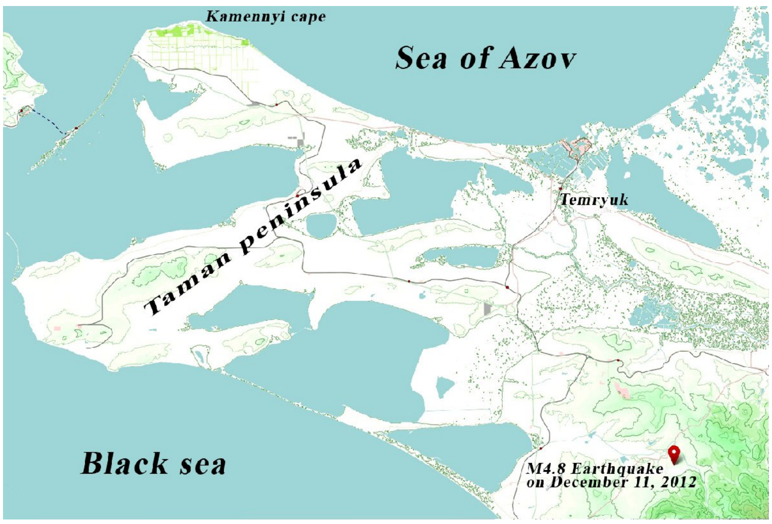

Fig. 1: Map of the Taman peninsula.

Series of earthquakes have occurred near the Taman peninsula zone over a period of October-November, 2011.

On December 11, 2012, at 20-50 Moscow time, there was an M 4.8 earthquake approximately 60 km to the northeast of the Kamennyi cape (Fig. 1).

Monitoring of the anomalous zone

The April 30, 2011 natural phenomenon was an infrequent occurrence. In November-December, 2011 full-scale investigations of the nature of an anomaly zone have taken place (Podymov and Podymova, 2012). Monitoring observations were carrying out for the Kamennyi cape till May, 2013. Fig. 2 and Fig. 3 show the Kamennyi cape state before and after Taman event.

Fig. 2: The Kamennyi cape state is on July, 2005.

Fig. 3: September, 2011. There is the bottom which was emerged above water after the Taman event.

Results of monitoring set forth below as the photo-histories. There is the Kamennyi cape state in at different time of observation. The Fig. 4 demonstrates an elevation of the Kamennyi cape above the horizon on December 1, 2011.

Fig. 4: The Kamennyi cape state is on December, 2011.

Half a year later, the surface of the cape was gone down about 1m relative the horizon (Fig. 5).

Fig. 5: The Kamennyi cape state is on June, 2012.

A rate of subsidence of the cape has sharply decreased during next half a year (Fig. 6).

Fig. 6: The Kamennyi cape state is on November, 2012.

The new coastline is particularly vulnerable to waves, wind and other natural factors. The Fig. 7 illustrates headland condition 2 years later the happened event.

Fig. 7: The Kamennyi cape state is on April 29, 2013.

A hypothetical model of event

To co-ordinate enumerated above events, we'll examine tectonic structure of the analysis area. Lithospheric plates are here in the mixed interacting (Fig. 8). Some authors divide this region into several microplates that together define the relative motions between the larger Crimea and Caucasus plates; these have contact over Kerch-Taman joint fissure, which one lays along the Strait of Kerch.

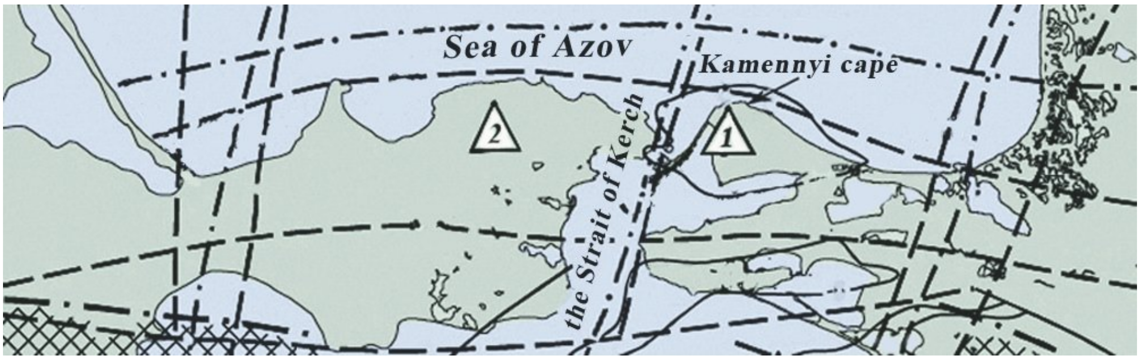

Fig. 8: Tectonic structure of the Kerch-Taman region: 1 - North-Taman microplate, 2 - Crimea microplate.

Depth profile for the region is shown in Fig. 9.

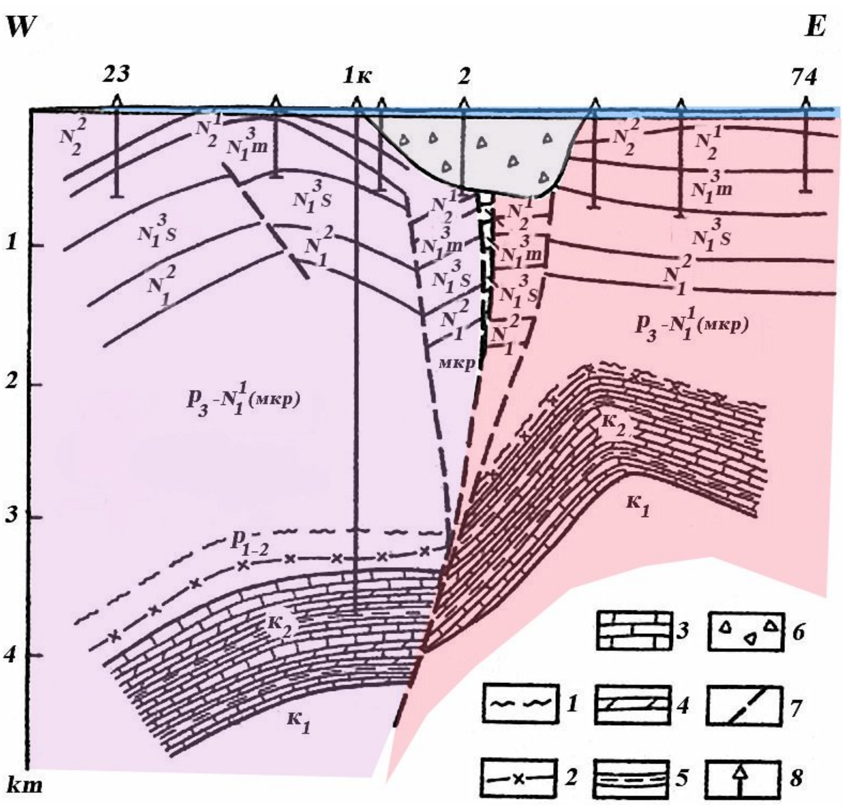

Fig. 9: Abyssal geologic section of the analysis area: 1 - a scour line; 2 - reflective seismic horizon; 3 - chalkstones; 4 - dolomites; 5 - clay; 6 - breccia; 7 - fractures; 8 - boreholes; W - West; E - East.

It is visible from drawing: anomalous zone is placing on obduction microplate. This one has contact with the subduction microplate at a depth of 4 km.

The essence of the hypothesis is the following. Microplates of Taman region were shifted to East at the time of shear of Eurasia plate during the Fukushima earthquake. Effect of braking appeared during a stop motion. Crimea microplate has approached under North-Taman microplate by inertia and created tension.

The instantaneous lifting of the obduction microplate has not happened for two reasons. Firstly, the size of the obduction microplate is only two times less than the dimensions of the subduction microplate. Secondly, the obduction microplate contacts with the underlying plate by means of a viscous sublayer. Thereby the North-Taman microplate held by means of surface tension force additionally. The microplate moved slowly upwards, gradually coming off the underlying plate. Simultaneously to microplate moving from a lower position to a higher one deformation and cracking were of the neighbor plates. When the critical values of the subduction plate pressure exceeded the total value of the forces held the obduction plate, North-Taman microplate have separated from the underlying plate of the lowest order.

Mud volcanoes (as indicators of tectonic activity) have revived in the fractured zones of the microplate. Fig. 10 shows the crater of mud volcano “Azovskoe Peklo” in the state of reduced activity.

Fig. 10: “Azovskoe Peklo” mud volcano state is on reduced activity.

In Fig. 11 is shown the state of the same volcano on June, 2011.

Fig. 11: The state of the crater of mud volcano “Azovskoe Peklo” is on June, 2011.

Mud volcano "Gnilaya gora" located at the Eastern edge of the North-Taman microplate. We fixed intensive volcanic eruption on June, 2011 (Fig. 12).

Fig. 12: Mud volcano "Gnilaya gora". Here is a volcanic eruption on June, 2011.

Series of the M 3.0 earthquakes have occurred near the anomalous zone in October-November, 2011.

If to follow a hypothesis, in deep layers formed a short-term equilibrium after the happened emerging of the North-Taman microplate. Surface of the Eastern part of the Crimean microplate be placed under the Western edge of the North-Taman microplate. The direction of interacting forces has changed. The weight of the Western edge of the obduction plate was directed towards the surface of the subduction one. Abrasion of the plates in the place of contact and gradual subsidence of the North-Taman plate should have started. A pressure of the obduction plate was constantly decreased, the speed of its sinking diminished in intensity therefore. We watched this effect from a surface, performing photographic survey of Camennyi cape position relative to horizon. The continuing of secondary tectonic activity should affect to the neighbor plates. So it is possible to explain the cause of earthquake on December 11, 2012, which occurred approximately 15 km from the Eastern edge of North-Taman microplate on depth of 22.4 km. The earthquake possibility has been forecasted in December, 2011 (Podymov and Podymova, 2012).

Changing the elevation of Camennyi cape over a sea surface is presented in Fig. 13. The figure shows, the North-Taman microplate a rate of subsidence varied from 3 to 25 cm per month during the monitoring.

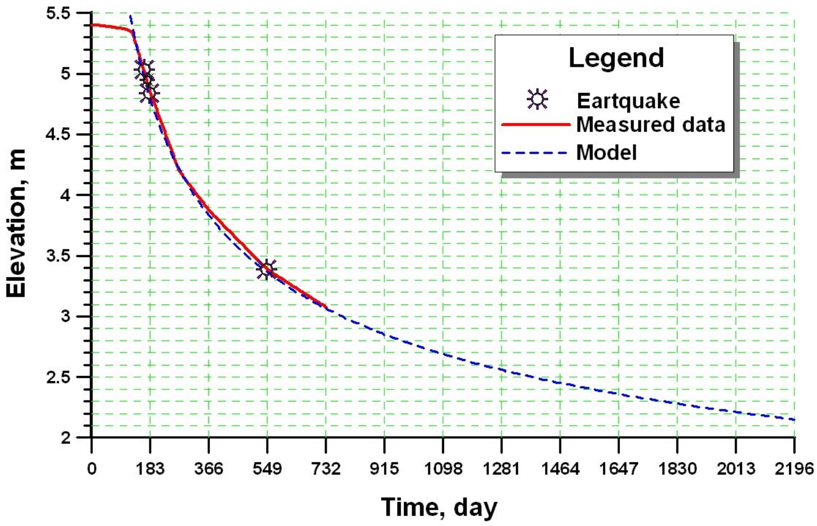

Fig. 13: Elevation changes of Camennyi cape over a sea surface: data of monitoring and mathematical model.

Approximating of monitoring data has allowed mathematical derivation of changing the elevation over a sea surface. The equation looks like (1).

$$\ln(Y) = -\,0.3228030356 \ln(61X/2) + 2.146247748 \qquad (1)$$

Here are: Y - an elevation over a sea surface, metre; X - time, day.

The plate a rate of subsidence is easy to calculate. According to this model, the plate will return to its original level after 37 years.

2-year observations have shown a break down of the newly formed beach happens with a rate of 10 - 15 m/yr (Fig. 14) under the influence of natural factors (wave height, a wind, an ice covering, etc.). By the end of 2014 «new land» will disappear out of sight.

Fig. 14: Fragment of the coastline of «new land» is on 18.11.2012.

Results of monitoring

Response to events of a large scale (like Fukushima earthquake) approximately 1.5 month.

The average a rate of microplate lifting is 1 m/h for concrete event.

The microplate a rate of subsidence obeys to equation.

The probability of earthquakes in region is high in the course of 3 years from the moment of the microplate lifting. Epicenters of earthquakes can be located at depths of 4 to 30 km.

Conclusion

Simplified physical model of interacting tectonic plates is only an attempt to search of causal the events that took place in region.

In accordance with the proposed model, the mechanism of the higher order tectonic plates interaction in the investigated region looks like “raised cock”, “twist-type trigger” for which will be possible the events, analogous to Fukushima earthquake.

Forecast of an emergency situations the region became possible due to model.

Acknowledgments

Researches were accomplished under the support of the Russian Foundation for Basic Research, grants 12-05-00946, 13-05-96508.

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Keywords

Tectonic plates, earthquake, Taman event, the Sea of Azov.